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Automating the Supply Chain: The Case for Autonomous Systems at Ports to Increase Resiliency

By: Jean-Luc Theard

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About the Author:

At the time of writing, Jean-Luc Theard is a rising senior at North Carolina State University, double majoring in Industrial and Systems Engineering and Political Science. He is a Benjamin Franklin Scholar, as well as formerly active in Student Government at his institution, and currently serving as an Industrial and Systems Engineering ambassador at NC State. His interest in the topic of port automation stems from an avid fascination in economic based issues, such as the supply chain crisis, and he hopes to extend that interest into consulting and federal government opportunities. He is originally from Winston-Salem, North Carolina and is an avid supporter of many Pennsylvania based sports teams such as the Pittsburgh Steelers and Philadelphia 76ers.

About the WISE Program:

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Acronyms and Definitions:

1. ACT: Automated Container Terminal
2. AI: Artificial Intelligence
3. CPPI: Container Port Performance Index
4. DOT: Department of Transportation
5. EPA: Environmental Protection Agency
6. FLOW: Freight Logistics Optimization Works
7. ILWU: International Longshore and Warehouse Union
8. ISA: International Society of Automation
9. MARAD: Maritime Administration
10. NDAA: National Defense Authorization Act
11. PIDP: Port Infrastructure Development Program
12. PMA: Pacific Maritime Association
13. TEU: Twenty-Foot Equivalent Units
14. UNCTAD: United Nations Conference on Trade and Development
15. ASC: Automated Stacking Cranes
16. AGV: Automated Guided Vehicles
17. CSLCA: Commercial Space Launch Competitiveness Act
18. Title 46 of U.S. code: U.S. laws with the focus on shipping [32].
19. ITA: International Trade Administration
20. FMC: Federal Maritime Commission
21. NPR: National Public Radio
22. U.S.: United States

Executive Summary:

This paper is an outline advocating for autonomous systems at ports across the United States. Due to the COVID pandemic, supply chain resiliency has become an issue across the nation. Port automation contributes critical advances to a broader supply chain resiliency solution. Due to the low productivity rankings of United States (U.S). ports when compared with foreign nations, unique solutions are needed. For port automation, complications such as implementation and workforce loss concerns discourage the implementation of these automated systems. Legislation goes so far as to explicitly discourage federally funded port automation activities [23]. Through the development of policies that encourage research and investigation into implementation practices and benefits, the nation can seek to encourage technological advancement while simultaneously balancing U.S. jobs.

Problem Statement:

500% is approximately the rise in shipping costs per container for trips from Shanghai to the U.S. money between 2020 and 2021 [34]. In other words, a massive twenty thousand dollars per container unit [34]. With continued focus on supply chains in all areas of governance, issues such as port backlogs and labor shortages in the trucking industry have taken center stage. From semiconductors to Nike shoes, products of all industries have seen backlogs at ports that have delayed their distribution to consumers across the nation. Increasingly concerning is the backlog's effect on inflation. According to a National Public Radio (NPR) article in 2021, at the height of this crisis, the Federal Reserve forecasted inflation to rise 3.4%, due in part to the crisis [33]. The negative effect this issue has on the economy exacerbates the need for unique solutions. Autonomous systems at ports do not provide a one size fits all resolution to supply chain crises of the past and the future, but it may be a piece to the puzzle in a more resilient U.S.

Background:

Situation

As with many industries, the Covid-19 pandemic changed a great amount in regards to supply chains and port management. U.S. ports saw record highs of ships waiting to dock and transport containers to shipyards. According to the Department of Transportation (DOT), the lowest number of container ships at sea waiting to berth around the nation was sixty-one between July of 2021 and 2022 [1]. May of 2021 saw the port of Los Angeles handle over one million Twenty-Foot Equivalent Units (TEUs) for the first time in its history, yet container ships saw seven day averages of waiting at sea to dock at the end of 2021. This was similar to averages of the entire year as well but twenty-one percent higher than at the beginning of the pandemic [2]. Many factors have contributed to the crisis that had plagued ports for most of the early 2020s. From an unprecedented rise in consumer demand during the pandemic, to a trucking workforce shortage of over eighty thousand, there is not a single area that one can pinpoint as to why the supply chain has suffered in the way it has [3]. What does bring hope is the increased amount of investment and attention that the federal government has given to this issue. The recent Bipartisan Infrastructure Bill has invested over seventeen billion dollars into port infrastructure [4]. The establishment of the Freight Logistics Optimization Works (FLOW) initiative by the Biden-Harris Administration also gives leverage for public and private entities to cooperate on transportation logistics around the country. These are just a few examples that see key stakeholders in the supply chain area share their interest in improving important areas of the business that envelops all of the U.S.. The chart below also illustrates the increasing investment in projects funded by the Maritime Administration (MARAD), specifically for the Port Infrastructure Development Program (PIDP).

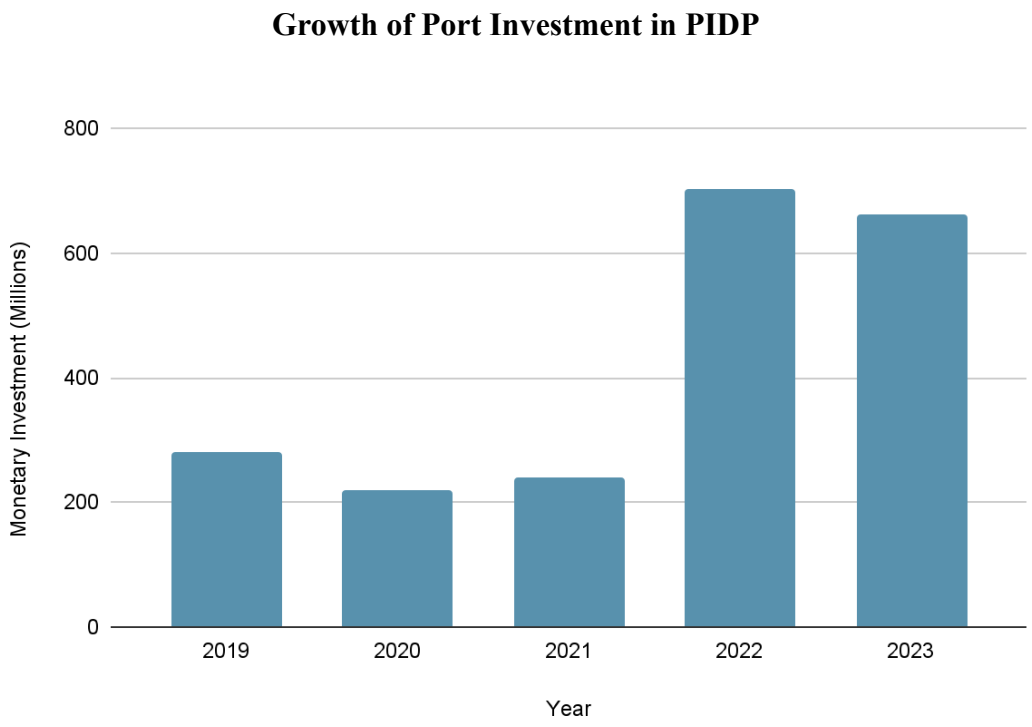

Figure 1 [5]

Although the pandemic has brought to light the issues of port and supply chain systems, these issues have been lingering. The World Bank's Container Port Performance Index (CPPI) saw no U.S. port ranked in the top seventy-five of efficiency metrics in 2020 based on containership processing according to an article from the CATO Institute [6]. Additionally, ports in the U.S. do not operate on a 24/7 basis compared to their Asian counterparts, which dominated that same index, with multiple in the top fifty. The U.S. loses around fifty-six hours of ships working to Asian ports, showcasing a lack of competitiveness that U.S. ports exhibit compared to the rest of the world [6]. With many other external factors affecting the operation of ports, public and private entities alike must find unique solutions to increase supply chain resiliency and prevent a similar catastrophe to that of recent years.

United Nations Conference on Trade and Development (UNCTAD) Challenges and Risk Factors to Port Resiliency

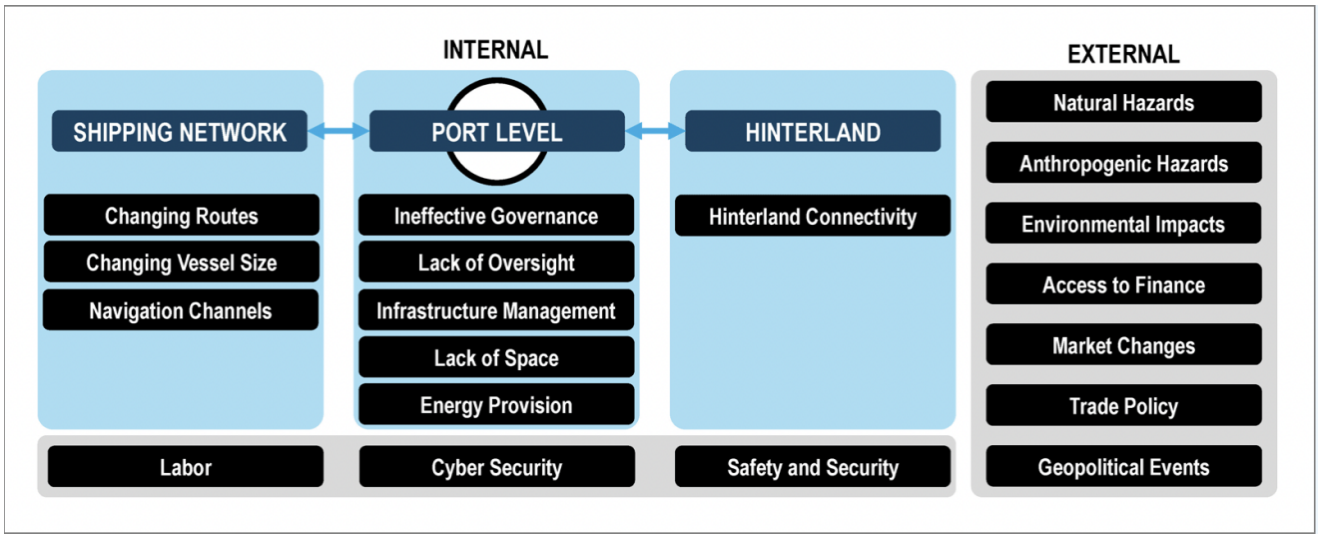

Figure 2 [7]

Covid-19 is not the only factor that can present challenges to ports. Natural hazards, governance and labor negotiations all contribute to delays and backlogs that ports experience regularly.

U.S. Port Rankings

One of the more reliable sources of statistical analysis of port performance, as stated before, lies in the World Bank's CPPI. The metrics used in this index include that of what are known as statistical and administrative approaches. Below is a representation of major U.S. ports and their rankings based on previous available CPPI's during the height of the pandemic and supply chain crisis. In this chart, the average ranking of the two approaches in the CPPI are calculated to give an encompassing overview of where U.S. ports stand. The rankings are out of 351 analyzed ports in 2020 and 370 in 2021 [8,9]. The given U.S. ports are all among the top ten ports in size, based on volume (in TEU), in the nation [10].

CPPI Average Rankings for Top U.S. Ports

Port:	2020 Index (Out of 351)	2021 Index
New York/New Jersey	Avg Rank: 108	Avg Rank: 251
Miami	Avg Rank: 157	Avg Rank: 34
Los Angeles	Avg Rank: 332.5	Avg Rank: 369.5
Long Beach	Avg Rank: 337	Avg Rank: 369.5
Savannah	Avg Rank: 187.5	Avg Rank: 367
Houston	Avg Rank: 254	Avg Rank: 121
Oakland	Avg Rank: 333	Avg Rank: 359.5
Virginia	Avg Rank: 97.5	Avg Rank: 25

Table 1 [8,9]

Los Angeles and Long Beach handle a combined 29% of U.S. cargo imports [11].

Based on these metrics, many major U.S. ports have not been competitive compared to international counterparts. This is also consistent at other ports, as cities such as Seattle and New Orleans boast rankings below two-hundred in both statistical and administrative approaches [8,9]. What is interesting to note though is the Port of Virginia's consistent performance as one of the top ports in the U.S., especially as the sixth largest port by volume [11]. The port saw rankings of twenty-seventh in statistical and twenty-third in the administrative approaches for 2021, an average rank of twenty-fifth, a major rise from its 97.5 average ranking in 2020 [8,9]. Diving into the methodologies of this port, especially as it is one of the sole users of autonomous systems in its terminals in the U.S., will be key to addressing the possibilities of autonomous implementations around the nation.

Port Operations Process

Below is a graphical representation of the process of port operations to provide background information. The main areas of port operations goes as follows according to the Environmental Protection Agency (EPA) [12]:

- Vessel Operation
- Cargo Handling (movement, inspection, etc.)
- Cargo Storage
- Cargo Transportation (via train or truck)

The Flow of Cargo at Ports

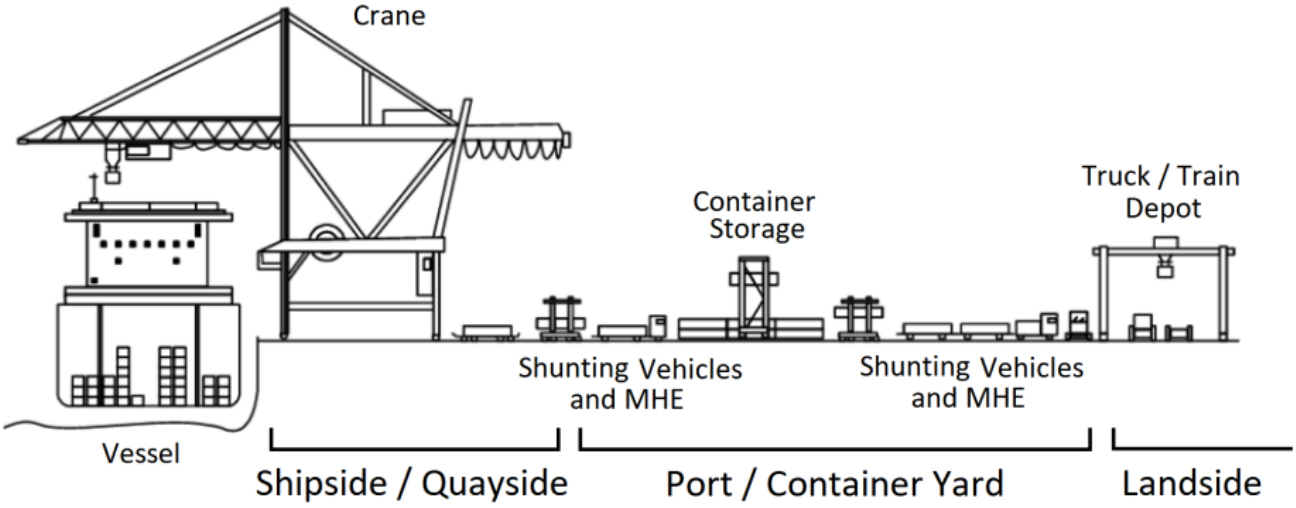

Figure 3 [13]

Autonomous Systems:

Background

In 1992, the first automated terminal was introduced in Rotterdam, Netherlands. Since that time, the steady increase of autonomous terminals has been tracked, as between 1993 and 2012, only twenty other terminals saw autonomous implementation within ports. That number doubled in

the time between 2013 and 2022, in which forty-one terminals saw autonomous systems implemented [14].

What does the term autonomous mean and how does it relate to port systems? Automation refers to the technique of making an apparatus, a process, or a system operate automatically according to the International Society of Automation (ISA) [15]. In regards to ports, certain research papers define it in terms of vertical and horizontal container movement, where semi-autonomous terminals solely incorporate vertical container movement, but fully autonomous terminals incorporate both vertical and horizontal movement of containers [14]. The definition can be extended into many avenues of port operations though, as the Port of Montreal has explored the implementation of Artificial Intelligence (AI) in many of their operations ranging from carbon emissions tracking to freight service [16,17]. This paper will focus mostly on the implementation of autonomous terminals by the definition given in the research paper cited above.

As of the recent journal article by Geraldine Knatz, Theo Noteboom, and Athanasios Pallis, only three percent of the world's port terminals foster autonomous capabilities in some capacity [14]. 5/63 of those terminals are housed in the United States. Comparatively, 17/63 East Asian terminals boast autonomous capabilities, and 13/63 European terminals do as well [14]. While the number of autonomous terminals is quite low in general, the United States' capabilities are even lower than other maritime and trade competitors. Considering the fifteen billion dollars McKinsey & Company projected to be invested in the industry in 2018, coupled with the growth in the number of autonomous terminals in recent years, the U.S. as one of the most advanced

nations in the world, must take a look into what is the cause of this uprise in technological improvement [18].

Examples of current autonomous port systems and what areas they are implemented

Continent/Region	Countries	Number of Ports
North/Central America	United States, Mexico, Panama	10
Europe	Belgium, England, Germany, Ireland, Italy, Netherlands, Spain	13
Asia	China, Japan, Korea, Indonesia, Singapore, Taiwan, India	23
Middle East	UAE, Israel	6
Oceania	Australia, New Zealand	7
Africa	Morocco	1

Figure 4 [14]

Outlined above are the current examples of autonomous nations and regions with autonomous port terminals based on the semi and fully autonomous definitions.

Research and metrics

As stated before, three percent of the world's port terminals boast autonomous capabilities. The question remains: Why the change? In most cases, automation trumps manual operations in many categories of efficiency and cost benefits. Prior to 2010, only thirty-two journal articles had been published supporting the argument that automatting port terminals can increase efficiency and productivity. Since 2010, ninety-seven articles have been published supporting

this argument [19]. Not only has the research in this area grown, but it increasingly supports the use of autonomous labor over that of manual labor.

The Cato Institute references data which compares crane processing of an Automated Container Terminal (ACT) in Rotterdam, and a manually processed terminal in Oakland. The cranes in Rotterdam in this case are nearly twice as efficient as those in Oakland, processing nearly 120,000 TEUs compared to Oakland's 66,000 [6]. This can also be reflected in the difference in average CPPI rankings that the two ports boast, with Oakland having an average 2020 rank of 333 and 2021 rank of 359.5 compared to Rotterdam's 103 and 299.5, respectively [8,9]. While the port of Rotterdam may not do as well as detractors of autonomous systems may expect, it still has outperformed the manual system of Oakland consistently and by relatively large margins.

Other sources of recognized research and surveys into autonomous system efficiency are referenced by the consulting firm McKinsey & Company, in which they took responses from a forum with the Shanghai international Port Group. Leaders within different port organizations, predicted that operating expenses would be cut by 25-55% and that productivity could be raised by 10-35% [18]. So in the case for autonomous systems at ports, what could be preventing them from being implemented on a mass scale? In this case, the vision of the situation is starkly different from the reality.

Complications:

Issues with Autonomous systems

In the same study from McKinsey & Company, survey respondents detailed the actual reality of many ports across the globe. Costs were cut by only 15-35%, a little less than predicted, but more concerningly, automation lessened productivity by around 7-15% [18]. If the reality of autonomous port operations does not meet the expectations, then the high cost of implementing these systems is not worth the investment. As seen by the completion of the Port of Long Beach's $1.5 billion decade long autonomous terminal project in 2021, it takes a monumental amount of time, money and effort to make these undertakings work [20]. The Pacific Maritime Association (PMA) references how "it can take fifteen years or more to implement automation and to pay it off through higher productivity." [21].

What are outlined as causes for these inefficiencies lie in capability shortages of experienced technical professionals to make these systems work, as well as missteps in implementation. With how costly autonomous capabilities are in the maritime sector, industry professionals must be able to get implementation down correctly in order for the field to thrive. Support from other sources is needed, and as outlined in the UNCTAD Challenges to Port Resiliency, ineffective governance and oversight up until this point has been an enormous internal challenge towards port resiliency [7].

Labor Unions

The most considerable complication that faces the implementation of autonomous systems in the U.S., especially on the West Coast, are labor unions. The International Longshore and Warehouse

Union (ILWU) organization has blocked many efforts to automate ports in recent years in contract negotiation holdups. Current legislation within federal acts such as the National Defense Authorization Act (NDAA) even helps in this regard. As of February of 2023, West Coast unions have still been in contract negotiation since May of 2022 [22]. In 2018, the Gulf and East Coast regions described labor contracts which provide “landmark protection against job-killing fully automated ports” [6]. The NDAA also provides similar wording in its description of how grant funding can be allocated to autonomous systems at ports. Section 3501 of the NDAA explicitly states “Limitation. - None of the amounts authorized to be appropriated for port infrastructure development activities…may be used to provide a grant to purchase fully automated cargo handling equipment that is remotely operated or remotely monitored with or without the exercise of human intervention or control, if the Secretary of Transportation determines such equipment would result in a net loss of jobs within a port or port terminal.” [23]. With the high salaries and benefits that port workers receive, averaging well over six figure salaries, it is clear why most would not be willing to give up their jobs that provide them their livelihoods. As said by the Los Angeles Times, port clerks average over $194,000, while foreman average $282,000 from values in 2020 [24]. Ports in the U.S. don't consistently work on a 24/7 basis like their global counterparts, contributing to the high costs and inefficiencies that drop top volume ports in the U.S. low on the World Bank’s CPPI. With a “worker-friendly” administration coupled with the benefits that port operators and employees receive on behalf of unionization, the path to autonomous implementation has a very tough road ahead for U.S. port authorities and companies [25]. The importance of worker rights and security has taken precedence at this point over technological advancement, but with recent issues arising at U.S. ports, one must wonder where compromise can be found.

Findings:

Current legislation

The importance that ports have taken as a subject matter in recent times cannot be overstated. Below are pieces of legislation in recent sessions, whether introduced into the House or Senate or farther along in the policy making process, that showcase the focus lawmakers have put on port infrastructure development as a key piece to improving supply chain resiliency:

- **The Resilient Ports Act** (Introduced by Rep. Peter DeFazio [R] in 2021): Act to expand upon eligible port infrastructure for grant funding [26].
- **H.R. 3395** (Introduced by Rep. Jake Auchincloss [D] in 2023): Funding research into foreign ownership of marine terminals based in the U.S. [27]
- **Ocean Shipping Reform Implementation Act of 2023** (Introduced by Rep. Dusty Johnson [R] in 2023): Technical corrections to title 46 of U.S. code [28].
- **S. 2113** (Introduced by Sen. James Risch [R] in 2023): A recently introduced bill to prohibit labor efforts from blocking modernization at ports [29].

The examples above paint a picture of the importance of ports to the federal government. Both parties are seeking solutions to the supply chain resiliency issue in the nation. What should be noted is that of two bills in this outline: S.2113 and H.R. 3395. These bills will be the basis to the policy recommendations given in this paper, even though they represent different sides of the political spectrum on this issue. One addresses labor restrictions and the other federal research into foreign influence on ports. Instead of staying separate on the two stances the parties hold on this topic, combining them should provide an avenue of bipartisanship in which addresses protecting jobs while simultaneously modernizing the nation's key supply chain infrastructure to actively bolster resiliency.

Executive Action

The executive branch has done a great amount of work towards increasing the resiliency of the supply chain through various programs. The main area of focus in regards to ports is that of the PIDP, which was established in 2019 to help fund infrastructure programs across all of America's ports [5]. The program itself has allocated around one billion dollars in funding to various projects and is a key staple to the advancement of ports and the competition that America's maritime industry seeks to promote [5]. The issue that comes at the expense of the advancement of these ports is that of their modernization in technology. Most ports, as stated above, still handle cargo in a manual fashion. The executive branch has seemingly been a part of hindering that in regards to section 3501 of the NDAA. The Secretary of Transportation's power in relation to the passing or failing of applications that are based on autonomous capabilities seemingly discourages these systems at ports. While money may not solve all issues, it can point the nation in the directions that the government wants it to go in, and under the Biden-Harris Administration, the direction is not in favor of autonomy.

For companies and port authorities to enable themselves to build upon autonomous infrastructure, they need the support and guidance of the government in order to foster that development properly. With how the current administration is handling the approach of autonomous systems, the discouragement of the technology will only hinder the advancement of the United States on a competitive level not just in maritime administration, but in the effects it has on other facets of the supply chain.

Case Studies:

Successful Autonomous system implementation in Ports (International)

The United States lags behind its European and Asian counterparts in ACTs Although these regions boast the most advanced ports and terminals in the world, that does not directly correlate to successful results, as seen by McKinsey & Company's study. Other ports such as the Port of Auckland in New Zealand saw issues in implementation as well, with a project being undertaken in 2016, but delayed by at least two years from its expected finish date in 2019 [37]. In contrast to this struggle, the most successful ports that have implemented autonomous terminals outside the U.S. consist of Antwerp, Barcelona, and Singapore, all consistently ranking in the top 100 ports in the world in the CPPI's 2020 and 2021 rankings [8,9]. Barcelona's semi automated terminal was implemented in 2012, and within 8 years has become one of the most productive terminals in the world, but this did not occur immediately [38]. The same article that delves into this also mentions how automated guided vehicles (AGVs) are more effective for ports with high labor costs and container traffic, specifying container traffic to over one hundred thousand containers per crane [38]. With areas like Singapore implementing autonomous systems for the future for its near thirty-million TEU capacity in 2020, major ports have set out goals for full autonomy [40]. Again, Singapore has a goal of 2040 to construct the world's largest automated port, a project set out since the 2010s [40]. The context of ambitious goal-setting and consistent year to year slow improvement of these systems at ports has given success to some of the largest and most integral ports in the world. Though with different regulations and practices within each nation, what can the U.S. draw upon in order to foster similar development? The answer may be closer to home than expected.

Successful Autonomous system implementation in Ports (Domestic)

As one of the most automated ports in America, the Port of Virginia is a case study of how autonomous systems can be properly implemented and produce effective results. The year of 2021 saw the port system handle a cargo increase of 25.2% successfully. [35] Comparing this to the Port's average ranking of twenty-five in the CPPI for 2021, Virginia's methodology stands as a model of success in a time defined by backlogs in other ports. The Chief Executive Officer of the Virginia Port Authority gives credit to autonomous systems along with other factors, saying "The terminal's automated stacking cranes means the port spends less time running extra shifts and burning out employees when ships are late" [35]. The Port of Virginia, which encompasses many ports within the state, is continuing to increase its investment in modernizing its infrastructure, with $650 million going towards Norfolk International Terminals, which includes adding eighteen semi-automated stacking cranes by 2025 [36]. Projections see the Port of Virginia's TEU capacity to increase to nearly five and a half million TEUs [36]. The Norfolk International Terminals has also recently invested over $140 million for thirty-six automated stacking cranes (ASC) which should be implemented by 2027 [37]. With all this in mind, what is the difference in which the Port of Virginia operates versus its domestic counterparts? The port produces more efficient turnarounds in its investment towards ASCs at its terminals, with lower amounts of funding. $217 million in 2016 that went towards eighty-six ASCs saw their usage contribute massively in its successful 2021, just a five year turnaround [35]. The future investments also signal quick implementation times compared to the fifteen year timelines of other ports given by the PMA. With a grand total of around one billion dollars in three projects compared to the Port of Long Beach's $1.5 billion project, the smaller more digestible investments seem to be more effective in implementation. Another positive aspect of the Port of

Virginia is its uniform model in governance. “In the Los Angeles area, the two ports are run by two distinct organizations.” [35]. The Hampton Roads terminals, Norfolk, Portsmouth, and Newport, are run by the state Port Authority, which makes for easier cargo diversions when backlog arises [35]. The model of uniformity and smart investment rather works for Virginia, and could be one for others to follow suit. With the high praise the port has received in its handling of the supply chain crisis, it’s one case study to look into for the future in regards to autonomous port systems.

Successful Autonomous implementation in other industry

The mining industry is an area that has seen advances in automation at a much faster rate compared to ports in recent years. These systems have been projected to save the industry well over $350 billion by 2025 [41]. What is more interesting to note is the intricacy in which autonomy is defined in this sector, with levels ranging from one through five describing the extent to which an area is automated, with five being fully autonomous and one providing operational assistance [41]. CSIRO, an Australian based research organization details its advancement into autonomous mining technology in 1994, a similar time period into which Rotterdam implemented its first ACT [42]. Why is it then that this industry has advanced farther than the maritime industry on the international stage? The benefits as detailed by the American Mine Services include safety, sustainability, and efficiency, all of which can be achieved in the maritime industry as well [43]. The same drawbacks with job loss though are also still considered. The major difference comes with the cost benefit of the implementation of these systems, as well as the higher frequency in which mining accidents occur. This has led to nations like Australia and even Canada to implement fully autonomous systems in the past decades [44].

With the benefits of cost efficiency and safety standards outweighing the possibility of job loss in the mining industry, exploring the benefits that port automation can implement is key to advancing it in the U.S.

Social considerations

In order to craft the necessary and most beneficial policies for this issue. Many factors must be taken into account. Outlined below are the considerations in which the given policy recommendations focus around:

Labor Unions

With the increased power and influence of labor unions in ports, policies must reflect a favorable position on workers rights and job outcomes. For years unions have been pushing against the implementation of autonomous systems, and with that there must be an understanding as to why this is the case. The motto of the Biden-Harris administration on autonomous systems is "Making automated systems work for the American people" [30]. The policies outlined below will follow this expression, in combination with legislative examples mentioned above, to foster a culture that encourages both technological advancement and unionization and labor.

Workforce transition

As seen in many other industries, most notably energy, workforce training and transition programs are key to aiding a workforce that is used to operations of old. The Biden-Harris Administration through the Bipartisan Infrastructure Law invested seventy-two million dollars in education and workforce development programs to promote "energy efficiency and emissions

reduction" and a "commitment to a clean energy workforce" [31]. The same theory in terms of workforce development can be applied to ports as well considering the troubles that many ports have had in implementation. Fostering a workforce trained to operate and manage autonomous systems will aid in making the transition to autonomy more efficient, while at the same time mitigating the job loss associated with it. The policy recommendations will take this factor into great consideration.

Increased productivity, efficiency, cost-savings

The final factor going into the policy recommendations focuses around the increased productivity and efficiency that these systems should provide. As stated in the complications section, the vision for autonomous systems and the reality are vastly different. By drawing from the various case studies cited above, the overlapping policies and standards that they implement should be able to give an outline as to how to properly execute autonomous systems at ports. This, coupled with workforce, and labor safety considerations should provide an all-encompassing guide for lawmakers to follow.

Recommendations:

The complexity and polarization of port automation make the task of developing policy recommendations that are considerate of both sides of the debate difficult. The main areas covered are that of safety, implementation and workforce consideration and are outlined below:

Congress must call upon the Department of Transportation to look into implementation practices of automation in order to amend Sect. 3501 of the NDAA.

With how vague and discouraging Section 3501 of the NDAA is towards automation, the federal government must provide a more specified outline of how companies and port authorities can implement these systems. Examples of legislative action taken in this direction are seen in the Commercial Space Launch Competitiveness Act (CSLCA), which "requires the Secretary of Transportation to submit a report of key industry metrics that might indicate the readiness of the commercial space sector…" [45]. The legislative action in this case should be similar to what Congress should call upon the Department of Transportation to conduct, which is an outline of specific metrics and data of what types of systems can be most efficient while mitigating job loss. Specific numbers of acceptable amounts of job loss, as well as acceptable ACS and AGV systems should be outlined, as well as admissible implementation practices and timelines for these systems. With research into these types of areas, port authorities and companies alike can have a better idea as to how they can best apply for government grant funding through the PIDP without worrying about if their application will be rejected on the basis of solely including autonomous systems in their application. Research like this can be done in conjunction with the Department of Labor, which can help look into areas of job loss mitigation. This will help encourage the adoption of automation at ports, while making sure that more systems take into

account workforce considerations and, as said by the White House motto on AI, “Making automated systems work for the American people”.

Workforce Development/Transition

As stated before, the reasons for the adoption of Section 3501 of the NDAA stem from the concerns that automation at ports have on the possibility of job loss. How this can be mitigated though is with the implementation of educational and workforce transitionary programs that allow for port workers to keep their jobs in a different capacity. The maintenance and upkeep of these autonomous systems is still crucial to their operation. As said in the McKinsey & Company study, implementation has been a struggle for autonomous terminals due to the lack of skilled and experienced workers, and the time it takes to get employees up to speed. With transitioning current port workers to these jobs, it allows for a lower implementation time as they are already acquainted with their specific port operations, as well as mitigating the net job loss at the ports. With the help of port authority organizations at the state and local levels to implement this, it gives power to each port to operate based on how they see fit. Congress should therefore call upon the Department of Labor to investigate and research into these programs and how they have been implemented and successful in other industries in order to provide a blueprint to the maritime industry.

Safety Standards

As seen in other industries that implement automation, safety standards are of utmost concern. ASTM International’s F45 committee on Robotics, Automation, and Autonomous Systems focuses its extent only on the practices of autonomous systems in manufacturing and logistics

[46]. Congress should therefore request the extent of organizations such as ASTM International and other standards and consulting organizations to investigate and cover the safety and practices of autonomous systems at ports in order to develop consensus standards into the handling of this equipment when implemented, to mitigate accidents that may occur within port terminals.

Efficiency Standards

The final recommendation comes in the form of mandating economic based organizations such as the Federal Maritime Commission (FMC), to research and investigate economic impacts of investment practices in autonomous systems. As seen in the comparison of the Port of Long Beach's $1.5 billion investment in an ACT versus the Port of Virginia's smaller investments and the results that each port has produced, the economic and cost benefit factors should be considered into what is best practice for ports across the country to implement. Attaining the aid of global organizations such as the International Trade Administration (ITA) and the World Bank can also be useful in cost-benefit analysis of ports across the world and how those areas have been the beneficiaries of autonomous ports such as Barcelona and Singapore.

Concluding Summary

Overall, the effects of the Covid-19 pandemic on the nation's supply chain have led to adverse effects in every industry. Rethinking the way the country moves products from producer to consumer in every facet of the process is key to building more resiliency. With the backlogs that ports saw in the early 2020s and its indirect contribution to the inflation we see today, advancement must be made on the infrastructure we see today.

Port automation offers benefits that are proven by research and in many cases real results in different areas. On the other hand, its effects on jobs and implementation issues in other cases bring about complications that make it difficult to execute on a large scale in the U.S. With certain case studies into other ports and industries that have embraced automation on a more grand scale, an outline can be given to the U.S. on how to properly make the systems of the future work for the people of today.

With the help of Congress and federal agencies alike, the use of research and public-private cooperation can delve into the intricacies of what makes autonomous systems more efficient, and how to implement them properly on a mass scale that works for the American people. While policies such as Section 3501 of the NDAA seek to protect the jobs of workers at these institutions, they do so at the expense of automation, while simultaneously pushing the problems they may bring further down the road. By addressing the polarizing matters of this topic, the nation can be better prepared for an advanced future in all sectors, and ensure that the American people are both protected and served in the most efficient way possible.

Citations:

1. “Supply Chain Challenges.” *Bureau of Transportation Statistics*, https://data.bts.gov/stories/s/Supply-Chain-Disruptions/5tut-fj6e. Accessed 11 July 2023.
2. Goodman, Peter S. “A Normal Supply Chain? It’s ‘Unlikely’ in 2022.” *The New York Times*, 6 February 2022, https://www.nytimes.com/2022/02/01/business/supply-chain-disruption.html. Accessed 11 July 2023.
3. McNally, Sean. “ATA Chief Economist Pegs Driver Shortage at Historic High.” *American Trucking Associations*, 25 October 2021, https://www.trucking.org/news-insights/ata-chief-economist-pegs-driver-shortage-historic-high. Accessed 17 July 2023.
4. Scott, Michelle P. “Understanding Infrastructure Legislation.” *Investopedia*, https://www.investopedia.com/here-s-what-s-in-the-usd1-trillion-infrastructure-bill-passed-by-the-senate-5196817. Accessed 11 July 2023.
5. “Port Infrastructure Development Program | MARAD.” *Maritime Administration*, https://www.maritime.dot.gov/PIDPgrants. Accessed 11 July 2023.
6. Lincicome, Scott. “America's Ports Problem Is Decades in the Making.” *Cato Institute*, 22 September 2021, https://www.cato.org/commentary/americas-ports-problem-decades-making. Accessed 11 July 2023.
7. “3.6 Port risk factors and challenges to resilience.” *UNCTAD*, https://resilientmaritimelogistics.unctad.org/guidebook/36-port-risk-factors-and-challenges-resilience. Accessed 11 July 2023.

8. Reya, Binyam, and Stuart Strachan. “The Container Port Performance Index 2020.” *maritimes.gr*, 10 May 2021, https://www.maritimes.gr/images/PORTS/Container-Port-Performance_Index-WB-2021.pdf?_t=1620669079. Accessed 12 July 2023.
9. Strachan, Stuart, and Nicolas Peltier-Thiberge. “CPPI Report.” *Public Documents | The World Bank*, 24 May 2022, https://thedocs.worldbank.org/en/doc/66e3aa5c3be4647addd01845ce353992-0190062022/original/Container-Port-Performance-Index-2021.pdf. Accessed 12 July 2023.
10. Ahmed, Zahra. “Top 10 Largest And Busiest Container Ports In The United States.” *Marine Insight*, 4 May 2023, https://www.marineinsight.com/know-more/top-10-largest-and-busiest-container-ports-in-the-united-states/. Accessed 12 July 2023.
11. “Facts and Figures | Statistics.” *Port of Los Angeles*, https://www.portoflosangeles.org/business/statistics/facts-and-figures. Accessed 14 July 2023.
12. “Ports Primer: 3.1 Port Operations | US EPA.” *Environmental Protection Agency*, 7 June 2023, https://www.epa.gov/community-port-collaboration/ports-primer-31-port-operations. Accessed 11 July 2023.
13. “Port Operations | Logistics Operational Guide.” *Logistics Operational Guide (LOG)*, https://log.logcluster.org/port-operations. Accessed 11 July 2023.

14. Knatz, G., Notteboom, T. & Pallis, A. Container terminal automation: revealing distinctive terminal characteristics and operating parameters. *Marit Econ Logist* 24, 537–565 (2022). https://doi.org/10.1057/s41278-022-00240-y
15. “What is Automation? - ISA.” *International Society of Automation (ISA)*, https://www.isa.org/about-isa/what-is-automation. Accessed 17 July 2023.
16. “Port of Montreal and GSTS launch AI project to reduce carbon footprint of vessels – Maritime.” *Maritime Magazine*, 21 March 2023, https://maritimemag.com/en/port-of-montreal-and-gsts-launch-ai-project-to-reduce-carbon-footprint-of-vessels/?utm_source=rss&utm_medium=rss&utm_campaign=port-of-montreal-and-gsts-launch-ai-project-to-reduce-carbon-footprint-of-vessels. Accessed 17 July 2023.
17. “To streamline the supply chain, the Port of Montreal is turning to AI.” *Le Port de Montréal*, https://www.port-montreal.com/en/the-port-of-montreal/news/news/ai-fluidity. Accessed 17 July 2023.
18. Chu, Fox, et al. “The future of port automation.” *McKinsey*, 4 December 2018, https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/the-future-of-automated-ports. Accessed 14 July 2023.
19. Kon, W. K., et al. "The global trends of automated container terminal: A systematic literature review." *Maritime Business Review* 6.3 (2021): 206-233.
20. Littlejohn, Donna. “Completion of Long Beach port's automated terminal hailed as creating a 'new bar' for the industry.” *Press Telegram*, 20 August 2021, https://www.presstelegram.com/2021/08/20/completion-of-long-beach-ports-automated-terminal-hailed-as-creating-a-new-bar-for-the-industry/. Accessed 14 July 2023.

21. Schmidt, Emily. “Why does the U.S. lag other nations so badly in the automation of its ports? — APM Research Lab.” *APM Research Lab*, 3 November 2022, https://www.apmresearchlab.org/10x-port-automation. Accessed 17 July 2023.
22. O'Mara, Kevin. “Three Reasons The ILWU Should Embrace Port Automation In LA/Long Beach.” *Forbes*, Forbes, 9 February 2023, https://www.forbes.com/sites/kevinomarah/2023/02/09/three-reasons-the-ilwu-should-embrace-port-automation-in-lalong-beach/?sh=57bdf90d43d7. Accessed 17 July 2023.
23. United States, Congress, House, Armed Services Committee, National Defense Authorization Act for Fiscal Year 2023, Congress.gov, 11 Oct. 2022, https://www.congress.gov/bill/117th-congress/house-bill/7900/text. Accessed: 19 July 2023.
24. Read, Richard. “Longshore union braces for bankruptcy, jolting national labor.” *Los Angeles Times*, 28 January 2020, https://www.latimes.com/business/story/2020-01-28/longshore-union-ilwu-bankruptcy. Accessed 17 July 2023.
25. Baertlein, Lisa. “Focus: Jobs at stake as California port terminal upgrades to green technology.” *Reuters*, 8 June 2023, https://www.reuters.com/sustainability/jobs-stake-california-port-terminal-upgrades-green-technology-2023-06-08/. Accessed 17 July 2023.
26. United States, Congress, House, Transportation and Infrastructure Committee, Resilient Ports Act, Congress.gov, 7 May 2021, https://www.congress.gov/bill/117th-congress/house-bill/3033/text?s=9&r=6&q=%7B%22search%22%3A%5B%22ports%22%5D%7D. Accessed: 19 July 2023.

27. United States, Congress, House, Transportation and Infrastructure Committee, U.S. Supply Chain Security Review Act of 2023, 17 May 2023, https://www.congress.gov/bill/118th-congress/house-bill/3395?q=%7B%22search%22%3A%5B%22ports%22%5D%7D&s=5&r=4. Accessed: 19 July 2023.
28. United States, Congress, House, Transportation and Infrastructure Committee, Ocean Shipping Reform Implementation Act of 2023, 28 March 2023, https://www.congress.gov/bill/118th-congress/house-bill/1836/titles?s=4&r=11&q=%7B%22search%22%3A%5B%22ports%22%5D%7D. Accessed: 19 July 2023.
29. United States, Congress, Senate, Health Education Labor Pensions Committee, PLUS Act of 2023, 22 June 2023, https://www.congress.gov/bill/118th-congress/senate-bill/2113/committees?s=1&r=16&q=%7B%22search%22%3A%5B%22ports%22%5D%7D. Accessed: 19 July 2023.
30. "Blueprint for an AI Bill of Rights | OSTP." *The White House*, https://www.whitehouse.gov/ostp/ai-bill-of-rights/. Accessed 18 July 2023.
31. "New Clean Energy Workforce Training Funding Available." *Department of Energy*, 7 December 2022, https://www.energy.gov/eere/iedo/articles/new-clean-energy-workforce-training-funding-available. Accessed 18 July 2023.
32. "OLRC Home." *OLRC Home*, https://uscode.house.gov/browse/prelim@title46&edition=prelim. Accessed 19 July 2023.
33. Horsley, Scott. "Cargo Is Piling Up Everywhere, And It's Making Inflation Worse." *NPR*, 21 June 2021,

https://www.npr.org/2021/06/21/1007938067/cargo-is-piling-up-everywhere-and-its-making-inflation-worse?ft=nprml&f=1054134188. Accessed 20 July 2023.

34. Khasawneh, Roslan, and Muyu Xu. “China-U.S. container shipping rates sail past $20000 to record.” *Reuters*, 5 August 2021, https://www.reuters.com/business/china-us-container-shipping-rates-sail-past-20000-record-2021-08-05/. Accessed 21 July 2023.
35. Pino, Dominic. “America’s Most Automated Port Had Its ‘Most Productive Year’ in 2021.” *National Review*, 12 January 2022, https://www.nationalreview.com/corner/americas-most-automated-port-had-its-most-productive-year-in-2021/. Accessed 22 July 2023.
36. “Revolutionizing Your Supply Chain.” *Port of Virginia*, https://www.portofvirginia.com/north-norfolk-international-terminal-optimization/. Accessed 22 July 2023.
37. Kontos, Ioanna. “Port of Virginia invests over US$140 million in automated cranes.” *Container News*, 5 May 2023, https://container-news.com/port-of-virginia-invests-over-us140-million-in-automated-cranes/. Accessed 22 July 2023.
38. “Automation of port terminals? Yes, but….” *PierNext*, 8 July 2021, https://piernext.portdebarcelona.cat/en/technology/automation-of-port-terminals-yes-but/. Accessed 22 July 2023.
39. Garrido, Javier. “The past, the present and especially the future of automation in container terminals - PierNext.” *PierNext*, 5 March 2020,

https://piernext.portdebarcelona.cat/en/technology/the-past-the-present-and-especially-the-future-of-automation-in-container-terminals/. Accessed 22 July 2023.

40. Koh, Ann. “Supply Chain Latest: Singapore's Port Wants to Go Fully Automated.” *Bloomberg.com*, 29 June 2022, https://www.bloomberg.com/news/newsletters/2022-06-29/supply-chain-latest-singapore-s-port-wants-to-go-fully-automated. Accessed 22 July 2023.
41. “5 levels of automation for the autonomous mine of the future.” *ABB*, https://new.abb.com/mining/mineoptimize/systems-solutions/mining-automation/5-levels-of-automation-for-the-autonomous-mine-of-the-future. Accessed 22 July 2023.
42. “Our history – Robotics and Autonomous Systems Group.” *CSIRO Research*, https://research.csiro.au/robotics/who-we-are/our-history/. Accessed 22 July 2023
43. “History of Mining Technology.” *American Mine Services*, https://americanmineservices.com/history-of-mining-technology/. Accessed 22 July 2023.
44. Werdann, Michelle. “Making autonomous mining safer.” *University of Nevada, Reno*, 27 February 2023, https://www.unr.edu/nevada-today/news/2023/autonodes. Accessed 23 July 2023.
45. “Scanned Document.” *Federal Aviation Administration*, https://www.faa.gov/about/plans_reports/congress/media/Sec.-111-Report-to-Congress-Evaluation-of-Commercial-Human-Space-Flight-Safety-Frameworks-and-Key-Industry-Indicators.pdf. Accessed 23 July 2023.
46. “Committee F45 on Robotics, Automation, and Autonomous Systems.” *ASTM International*, https://www.astm.org/committee-f45. Accessed 23 July 2023.